Event Horizon Telescope

NOVEMBER 10 - JOURNÉE DU LUTH

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FLARE ECHOS FROM RELAXATION WAVES IN PERTURBED RELATIVISTIC JETS

LUTH l'Observatoire de Paris | PSL
Laboratoire Univers et THéories


Event Horizon Telescope
3C 279
VLBA (7mm)
April 16, 2017
2000 μas

EMISSION FEATURES IN AGN JETS

- We can identify two main regions :
  - **Standing regions :** understood* as recollimation shocks in the jet,
  - **Moving regions :** understood* as moving ejecta (blob) in the jet.
- Efficient particle acceleration mechanism $\longrightarrow$ Fermi I*
- Flare event during shock - shock interactions ?

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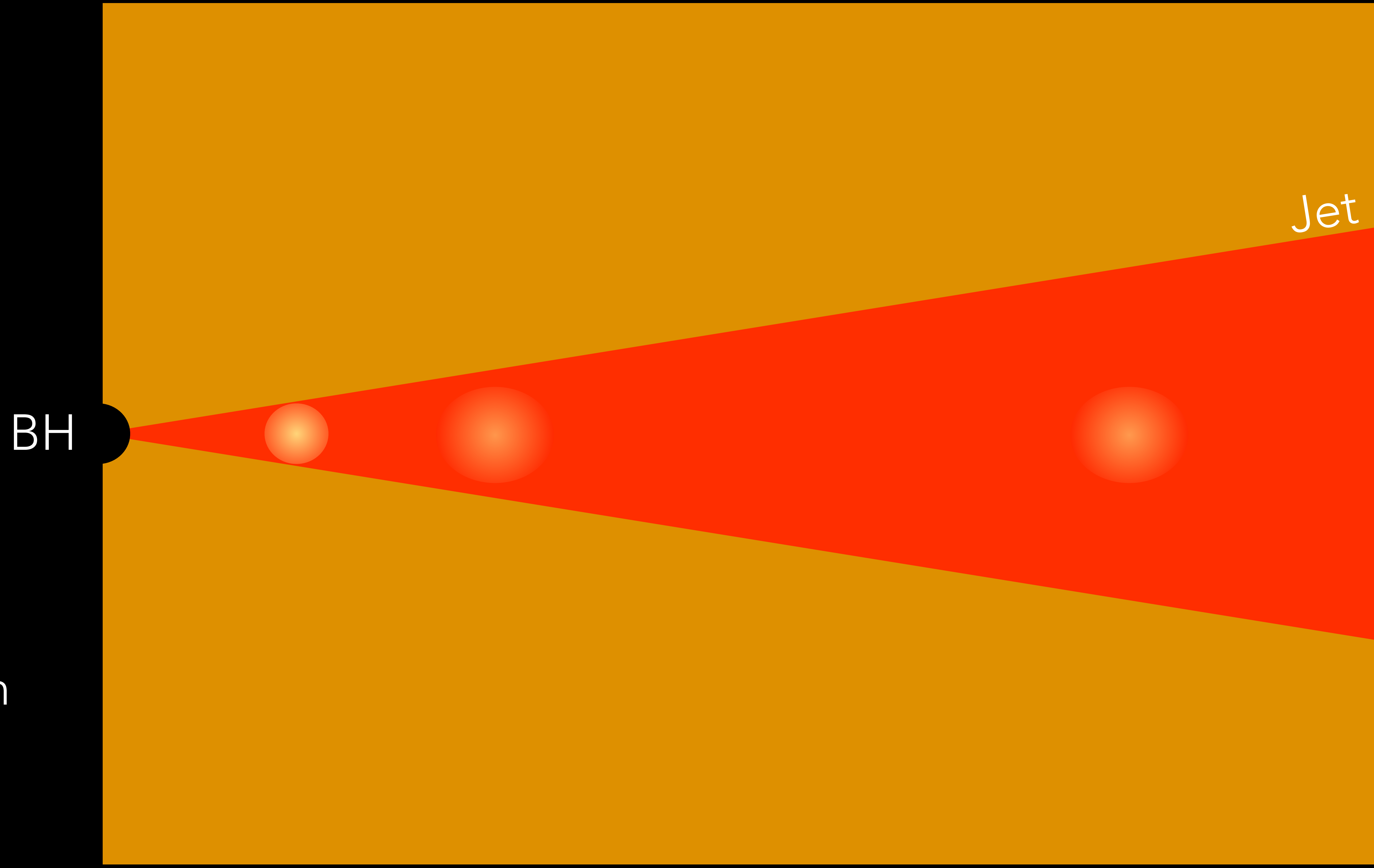

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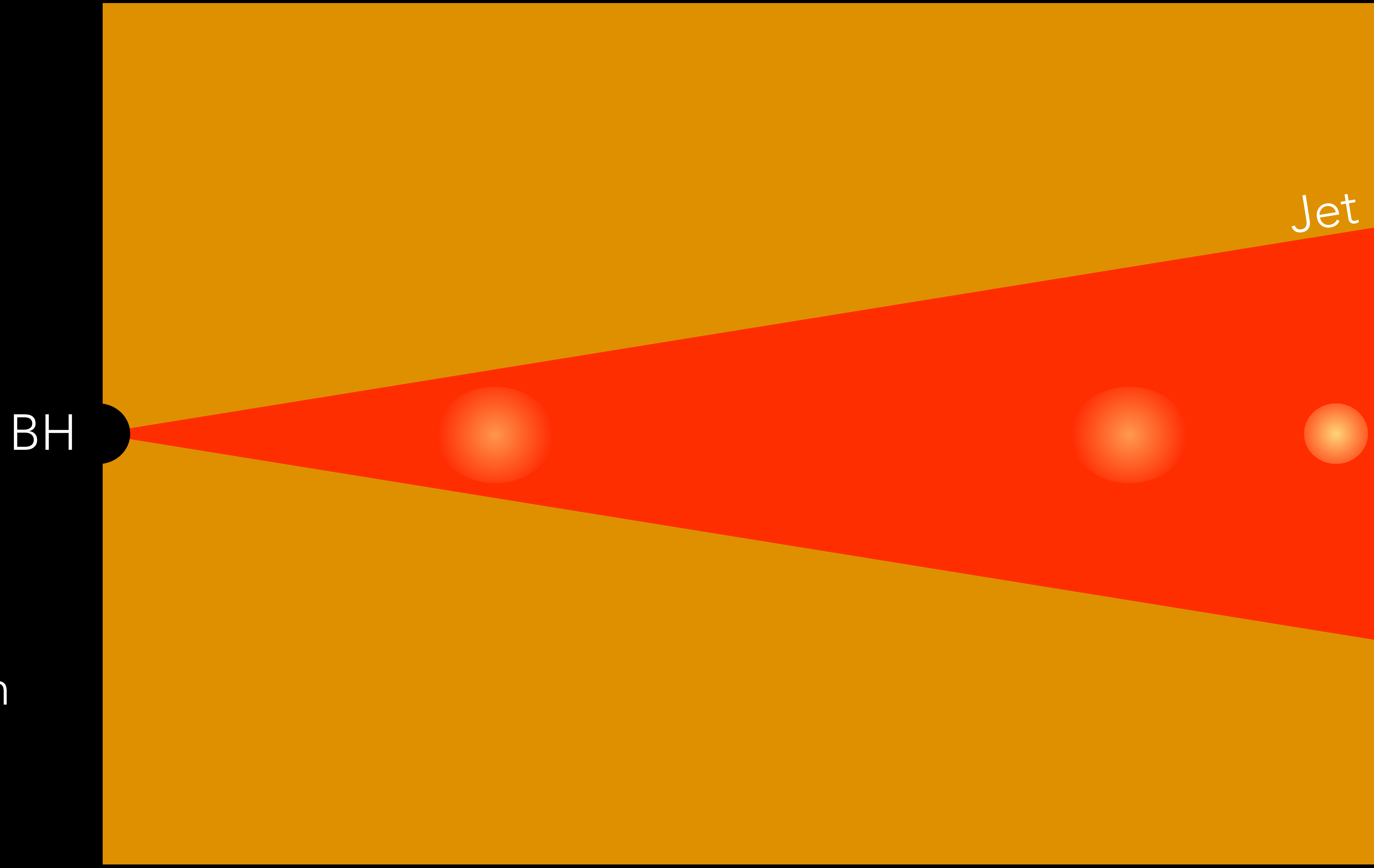
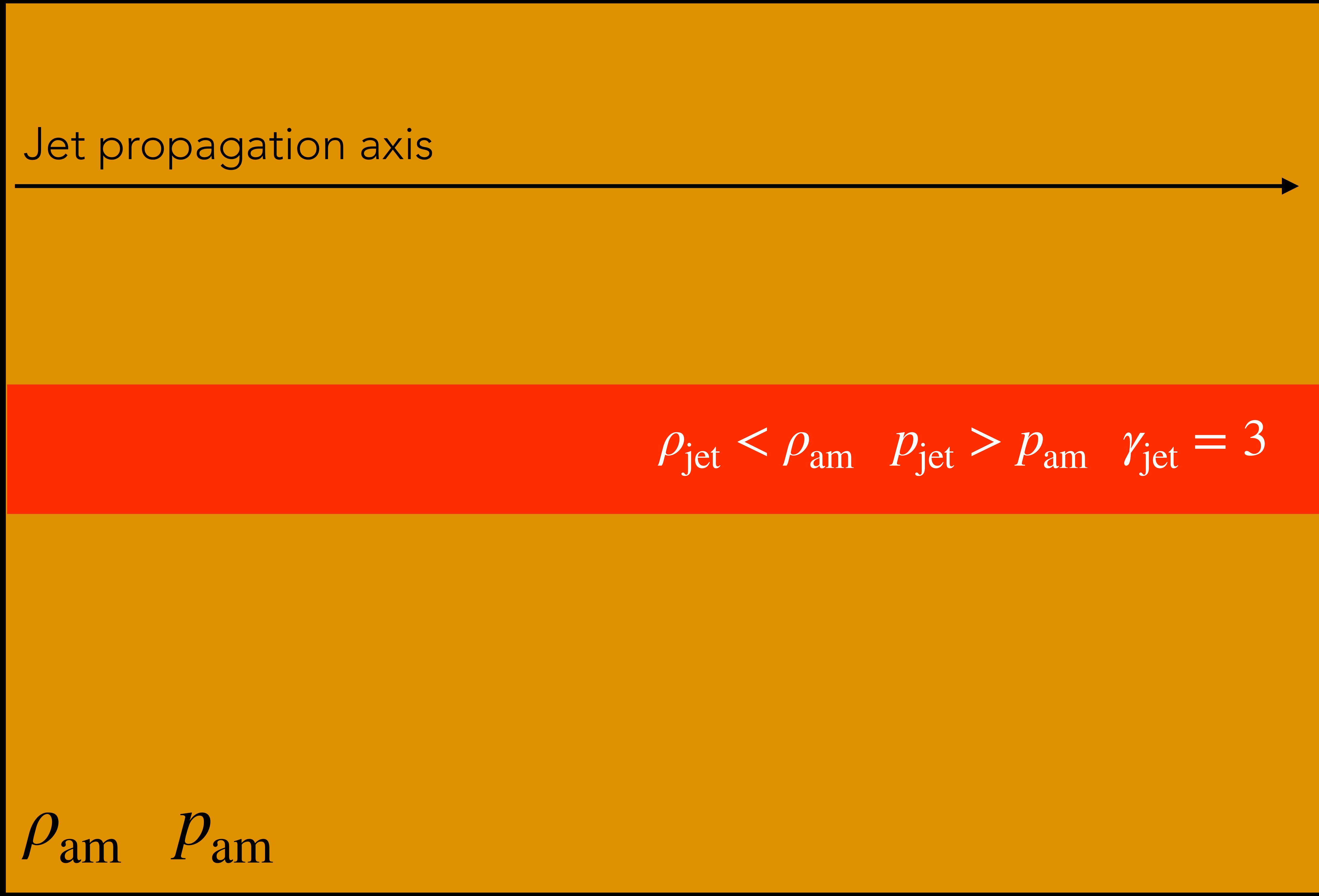


MODEL (1) : RECIPE FOR A RELATIVISTIC JET

1. Use the AMRVAC code [5] which can resolve SR-MHD equations inside an adaptive cell mesh.

2. Initial cylindrical jet set with initial conditions ($p, \rho, \vec{B}, \cdots$).

3. To reproduce standing knots : use an over-pressured jet [2, 3] (compared to the ambient medium) : $p_{\mathrm{jet}} > p_{\mathrm{am}}$.



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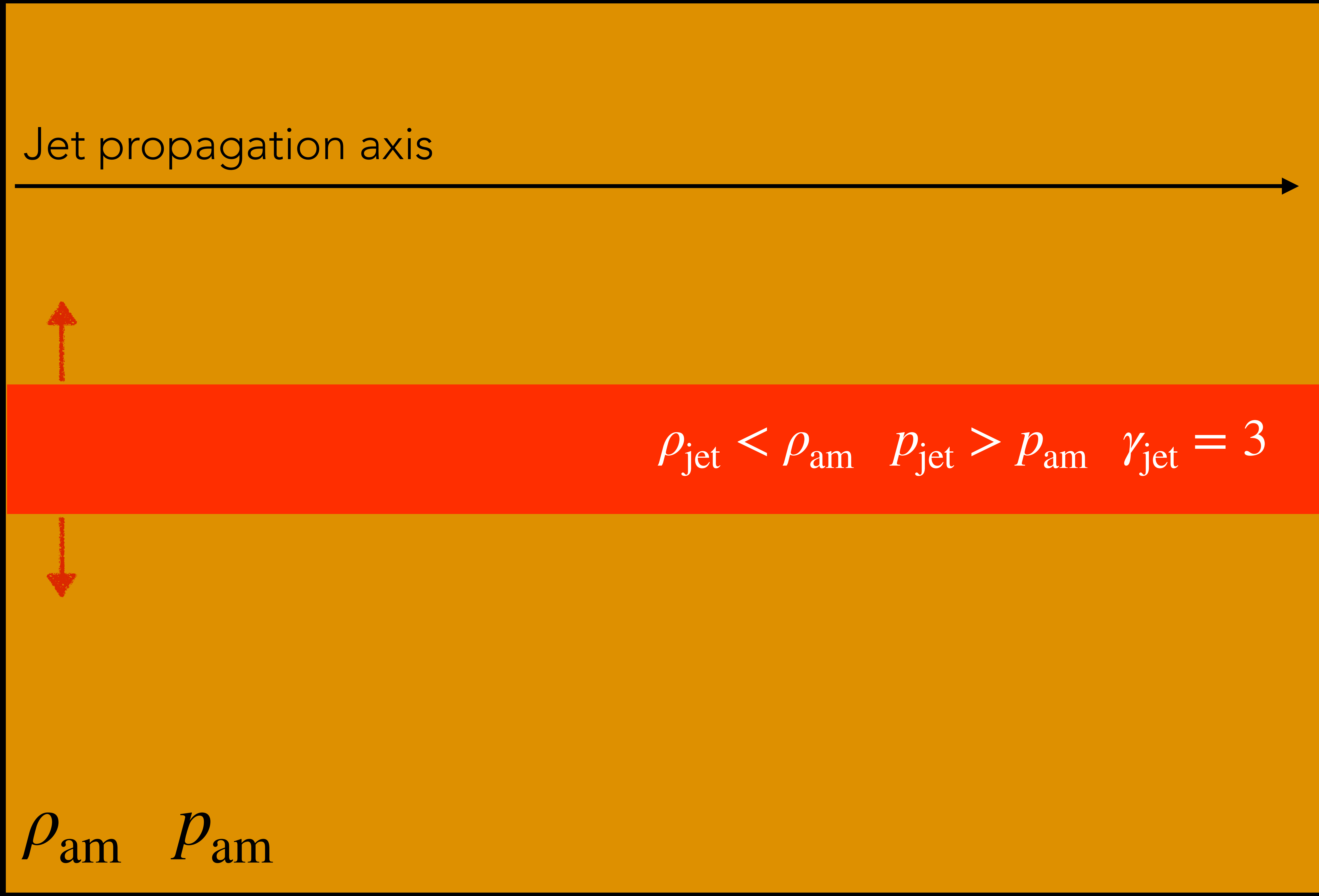

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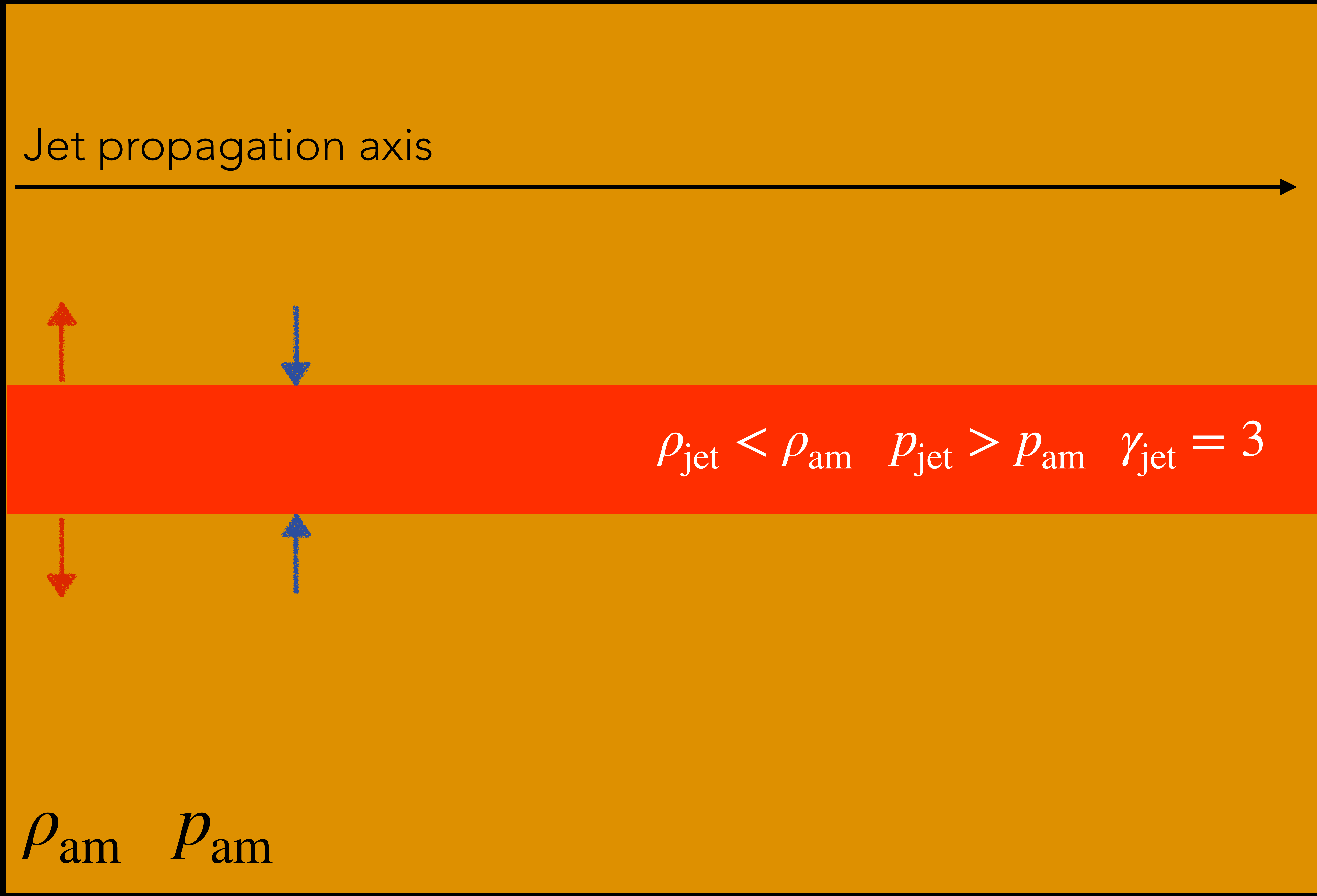

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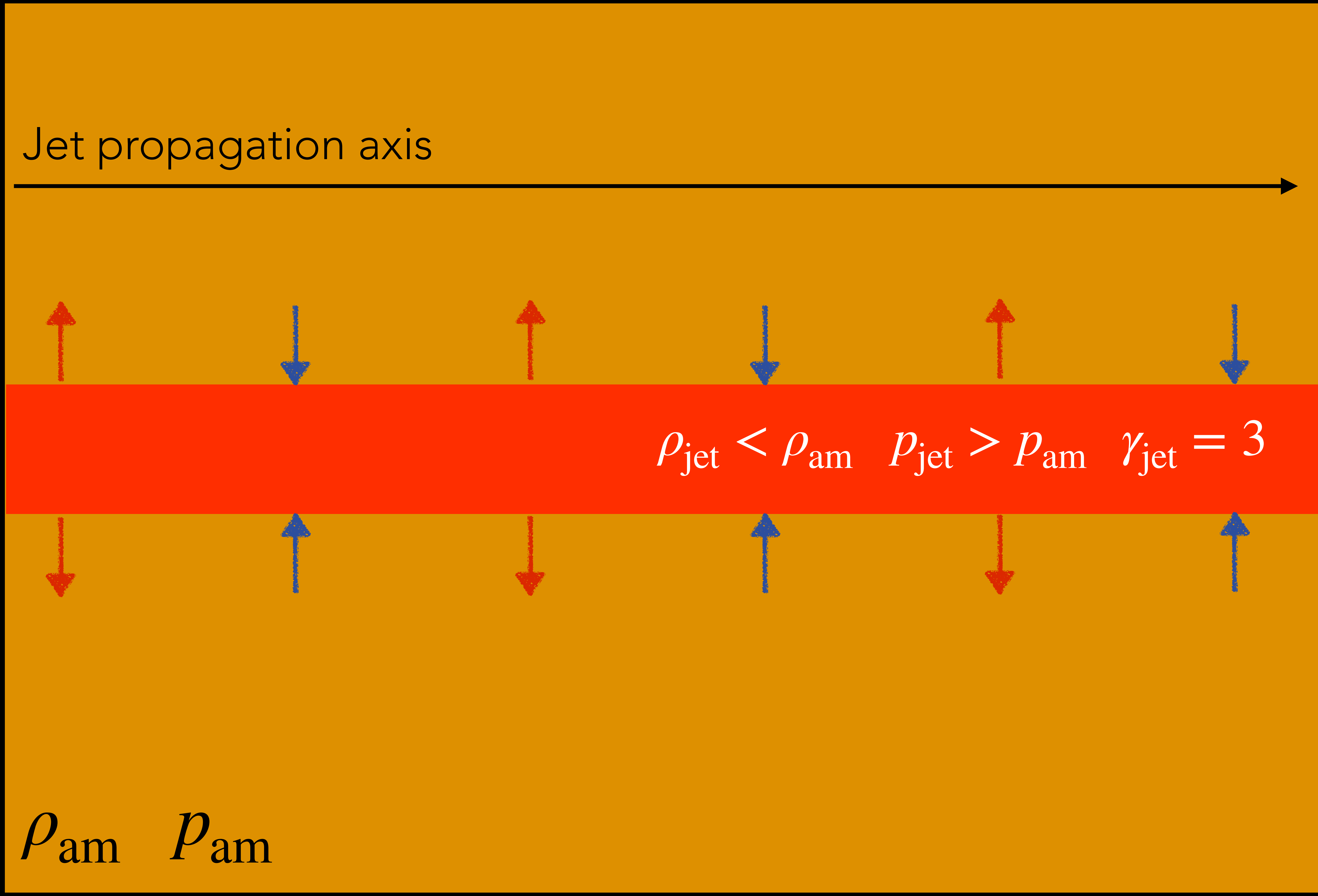
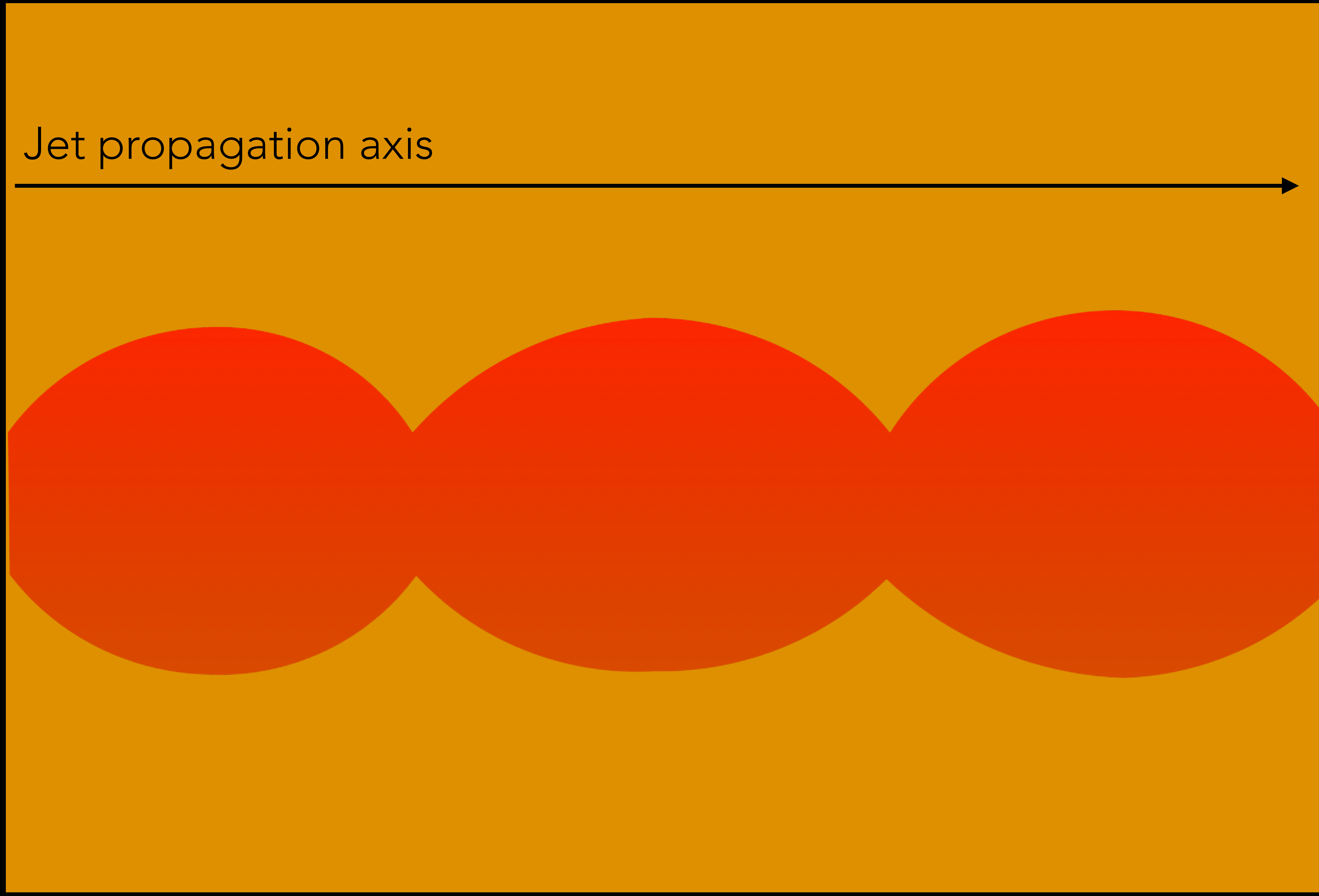


MODEL (1) : RECIPE FOR A RELATIVISTIC JET

4. Detect the shock regions in the jet by checking variations of $\mathscr{M}$.
5. Inject relativistic electrons in shocks. We define an energy γ_e and a density n_e.
6. Check for radiative cooling : extract a fraction of energy along time [6].



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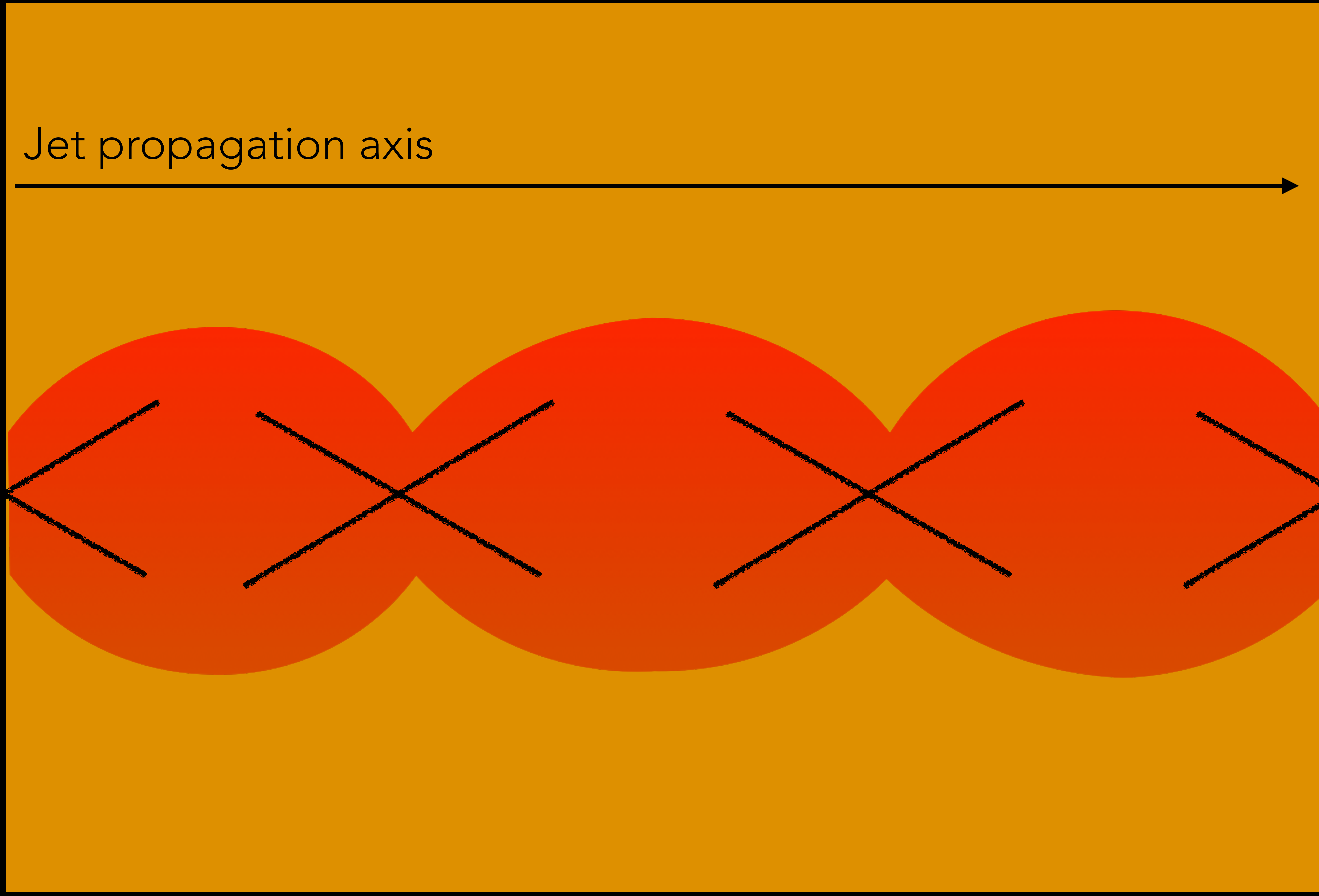

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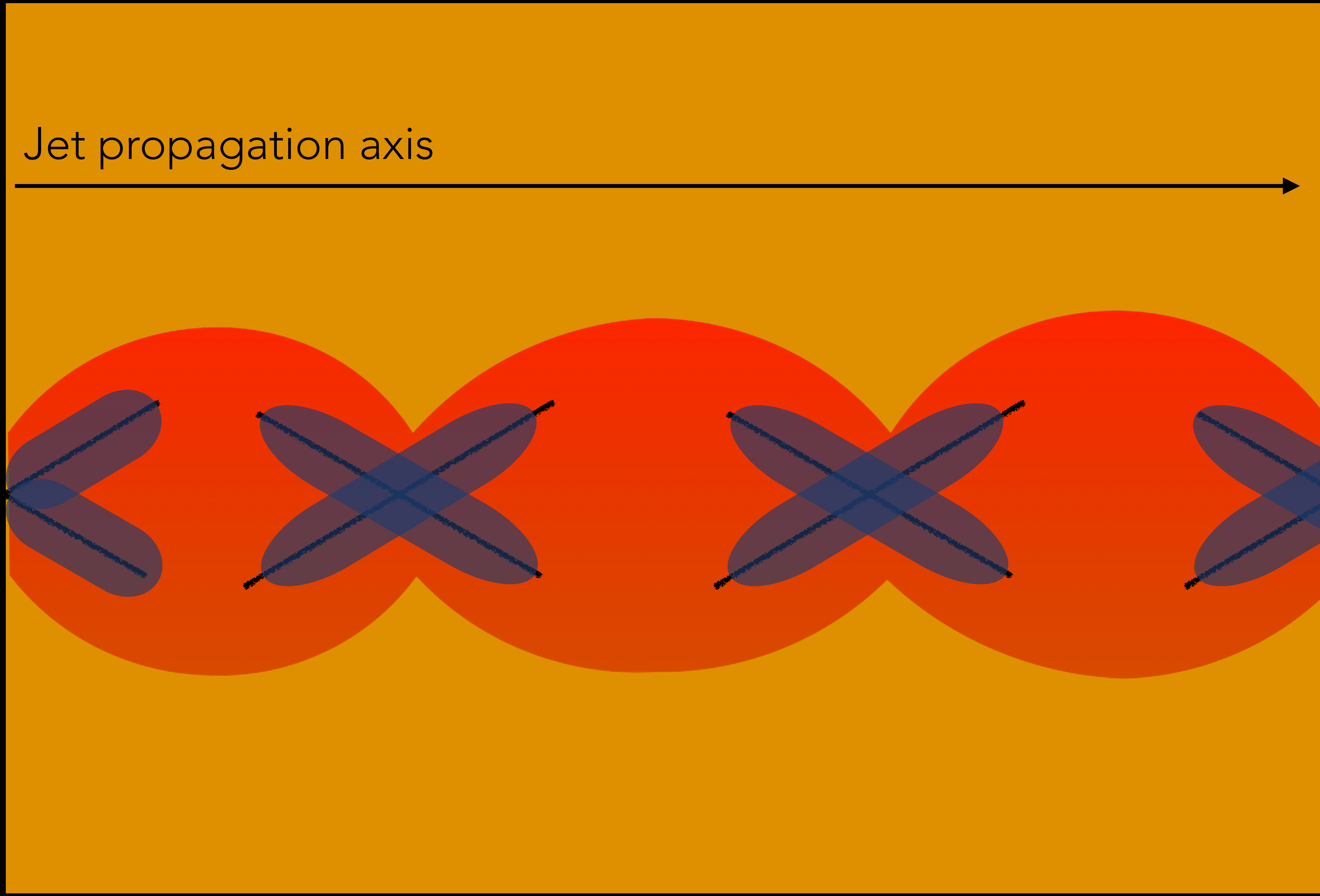
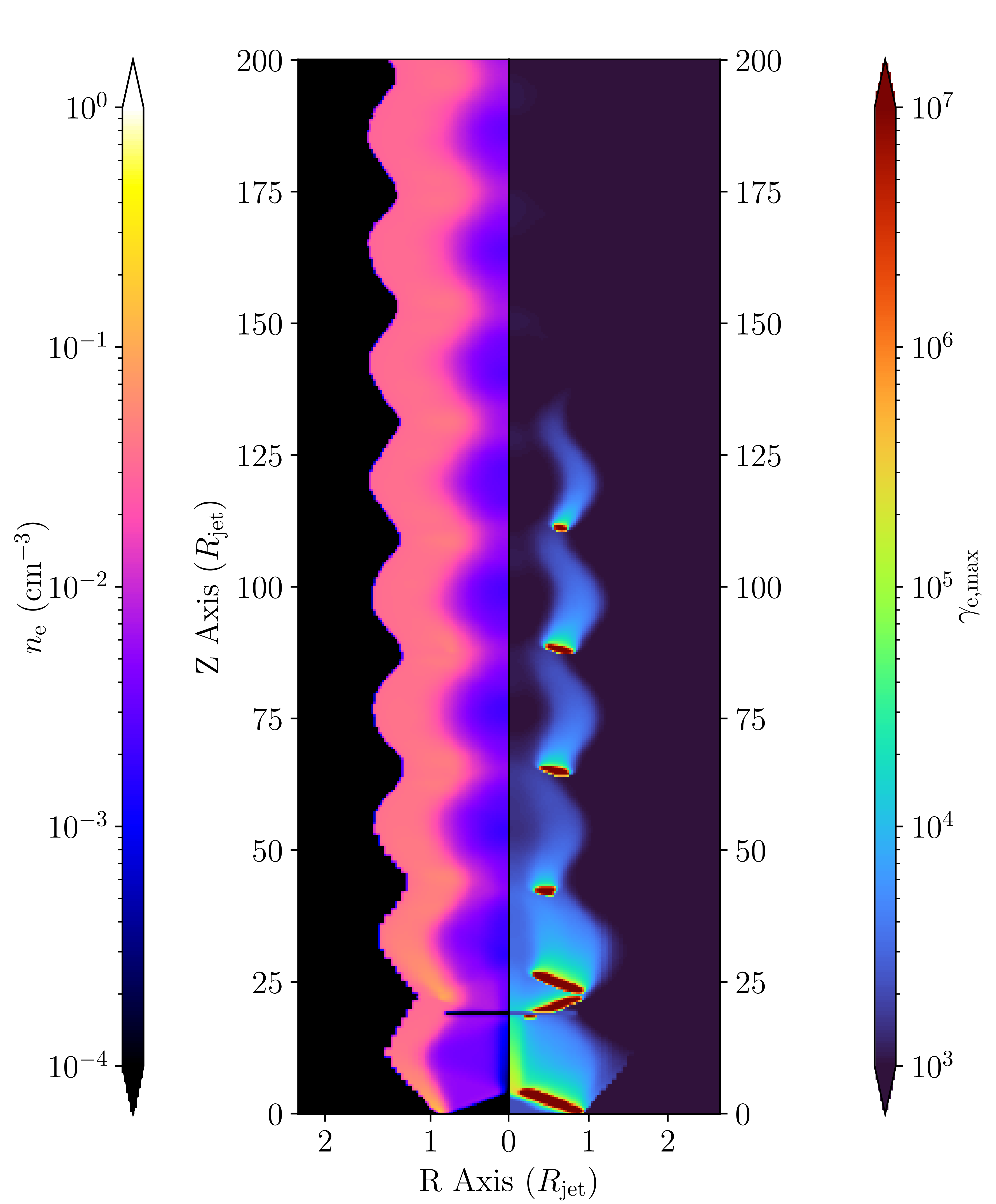


MODEL (1) : RECIPE FOR A RELATIVISTIC JET

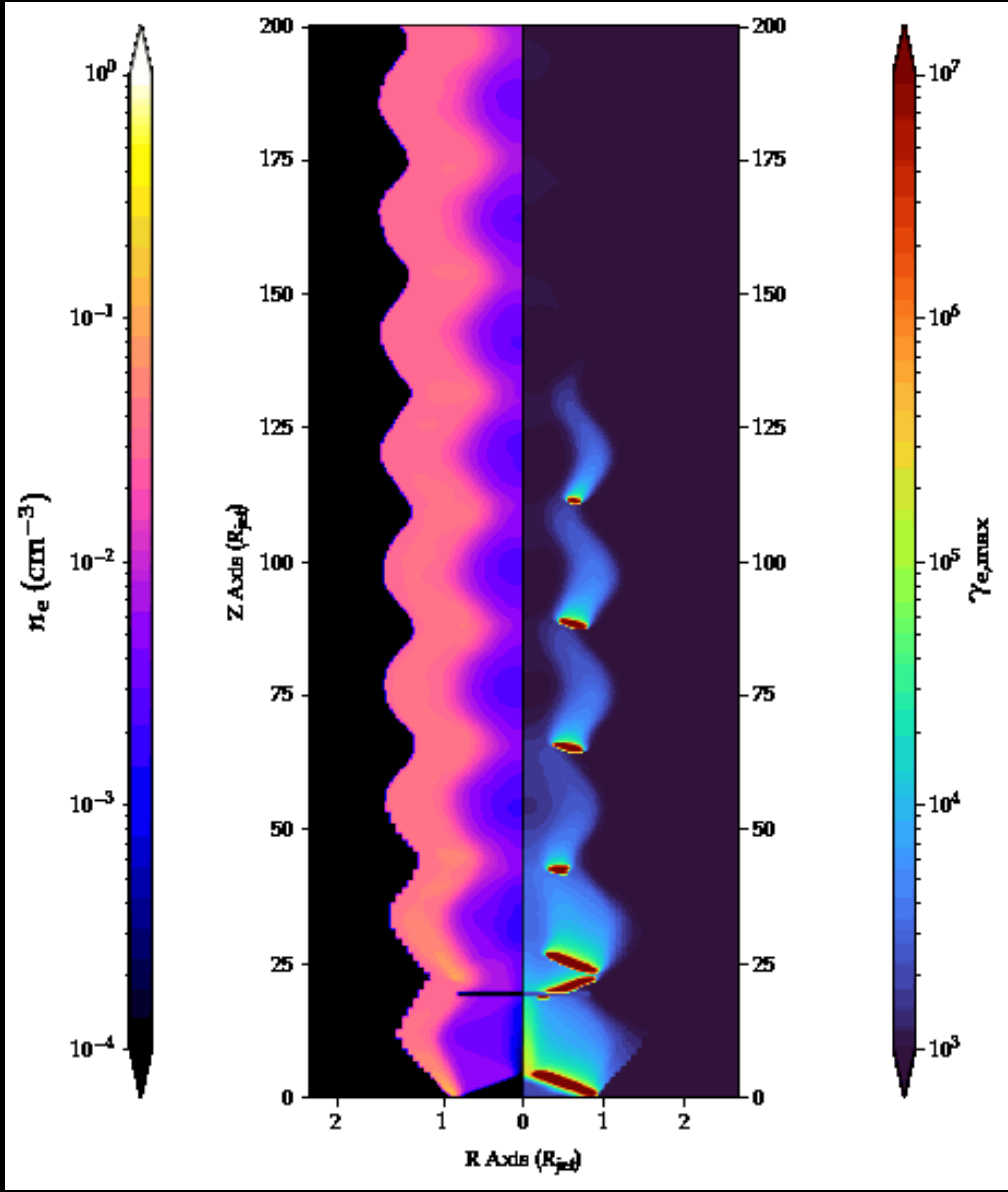
7. Launch computations on super-computer (such as CINES / Meso-PSL) and wait a few days.

Picture may differ from actual products…



MODEL (1) : AND THE EJECTA ?

- We inject an ejecta at the base of our jet with :
  - $\rho_{\mathrm{ej}} = \rho_{\mathrm{jet}}$, $p_{\mathrm{ej}} = p_{\mathrm{jet}}$ and $\gamma_{\mathrm{ej}} = 24$.
- It generates a moving shock able to inject relativistic electrons.
- Perturbations appear in the wake of the ejecta…



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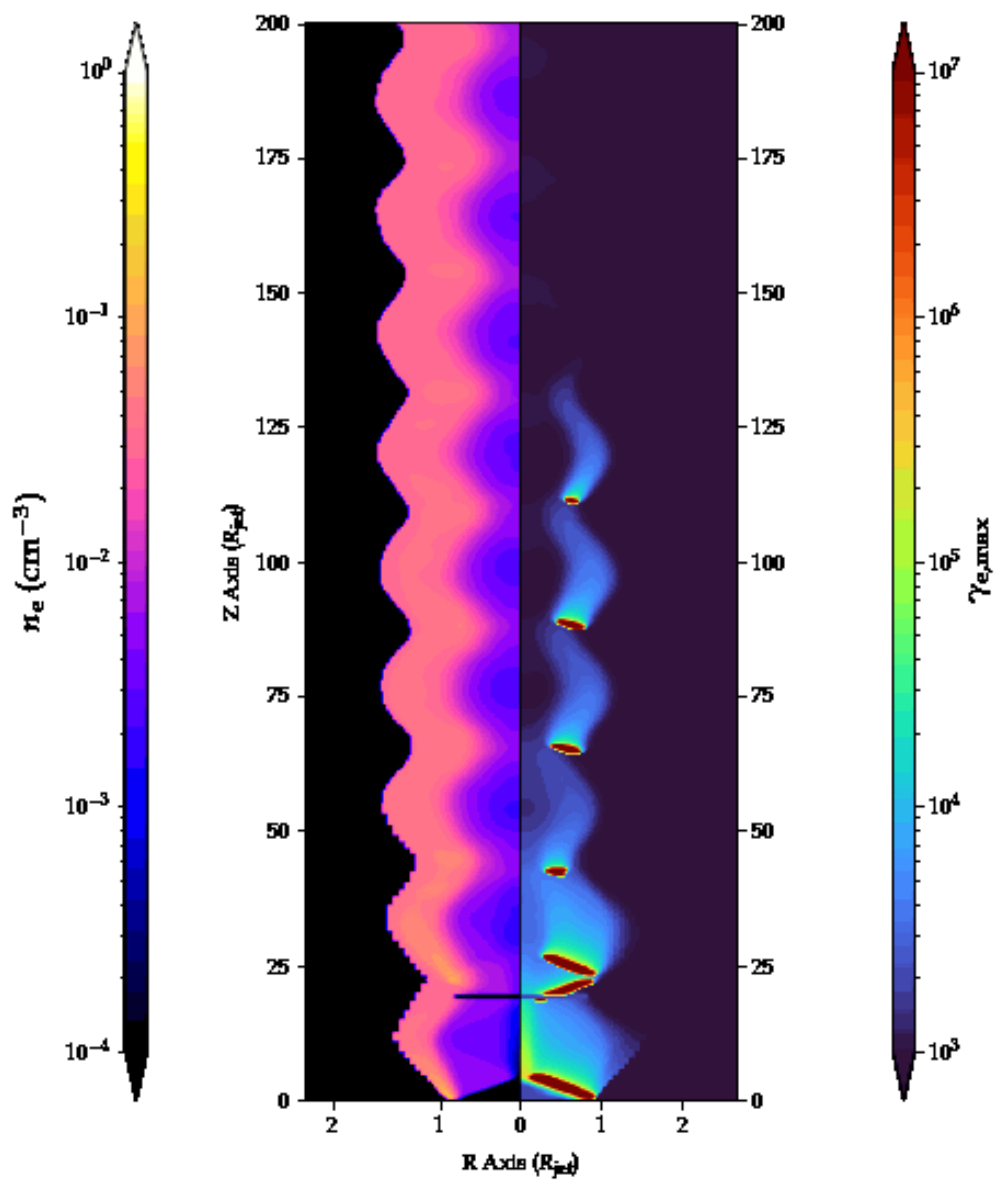
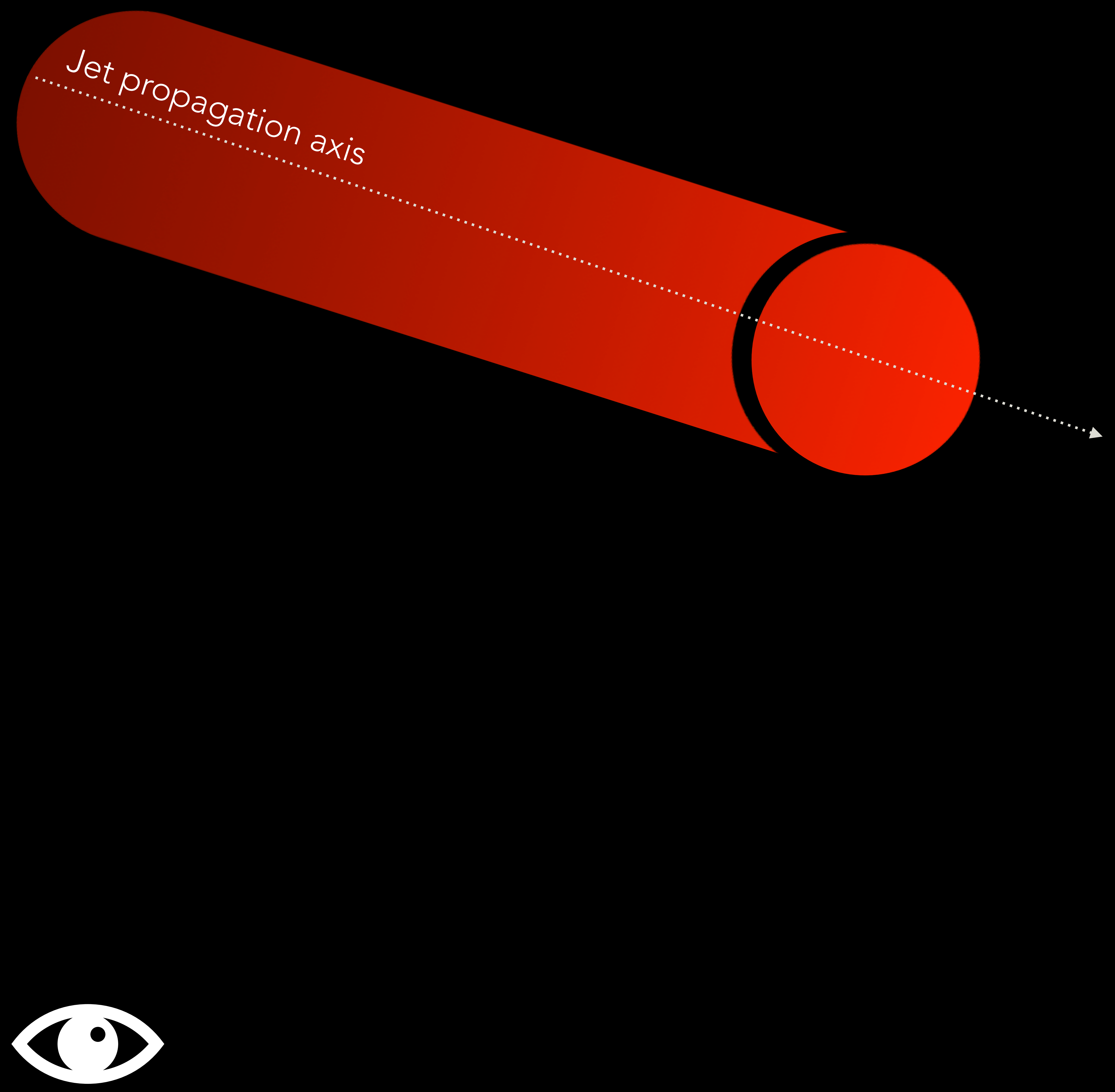


MODEL (2) : RIPTIDE CODE [3]

- *Radiation Integration Processes in Time-Dependent* code.
- Synchrotron parameters from relativistic electrons quantities (j_ν, α_ν, τ_ν).
- Resolution of the radiative transfer equation along a line of sight.
- Relativistic effects : Doppler beaming, light crossing time effect…



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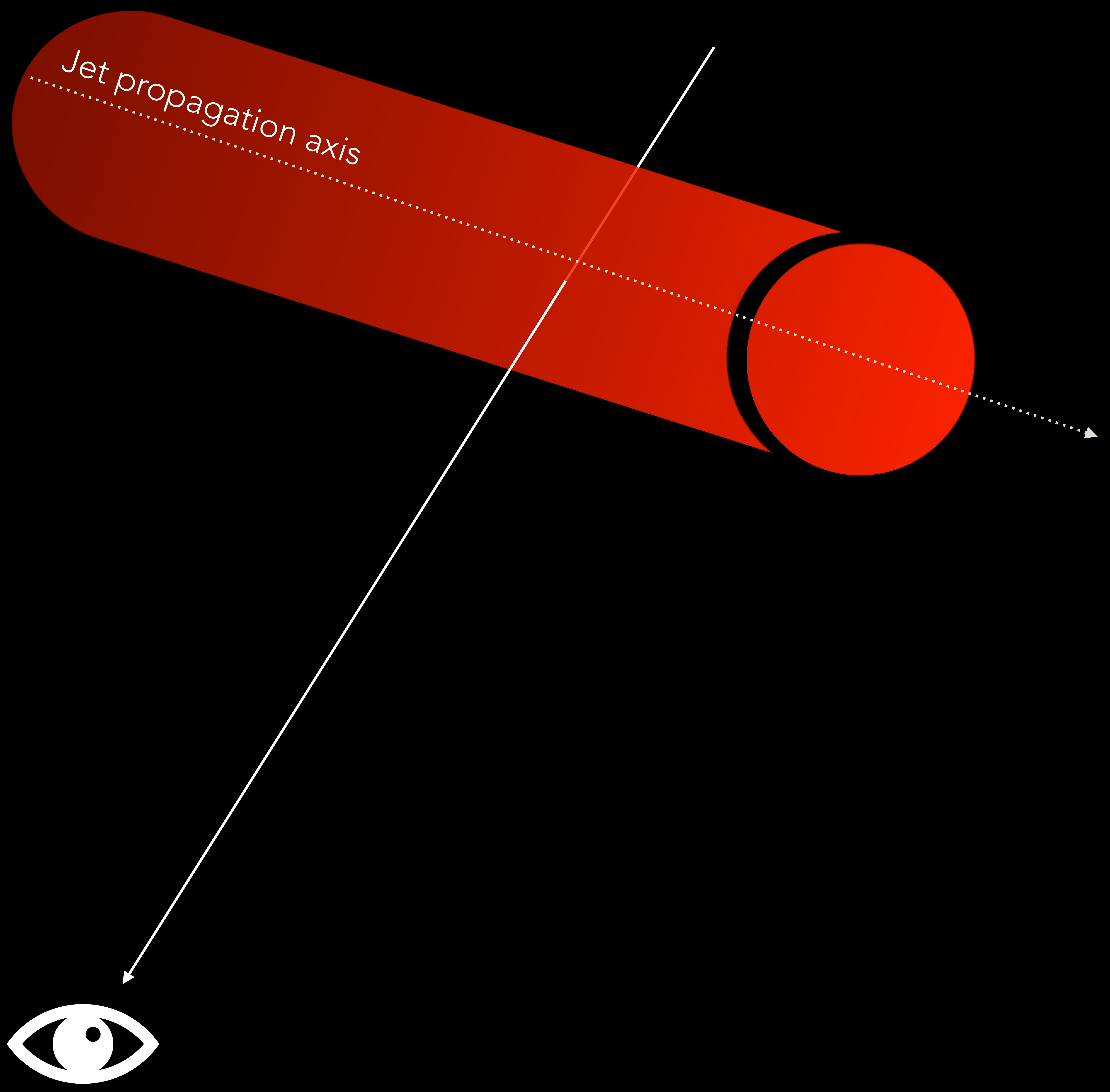

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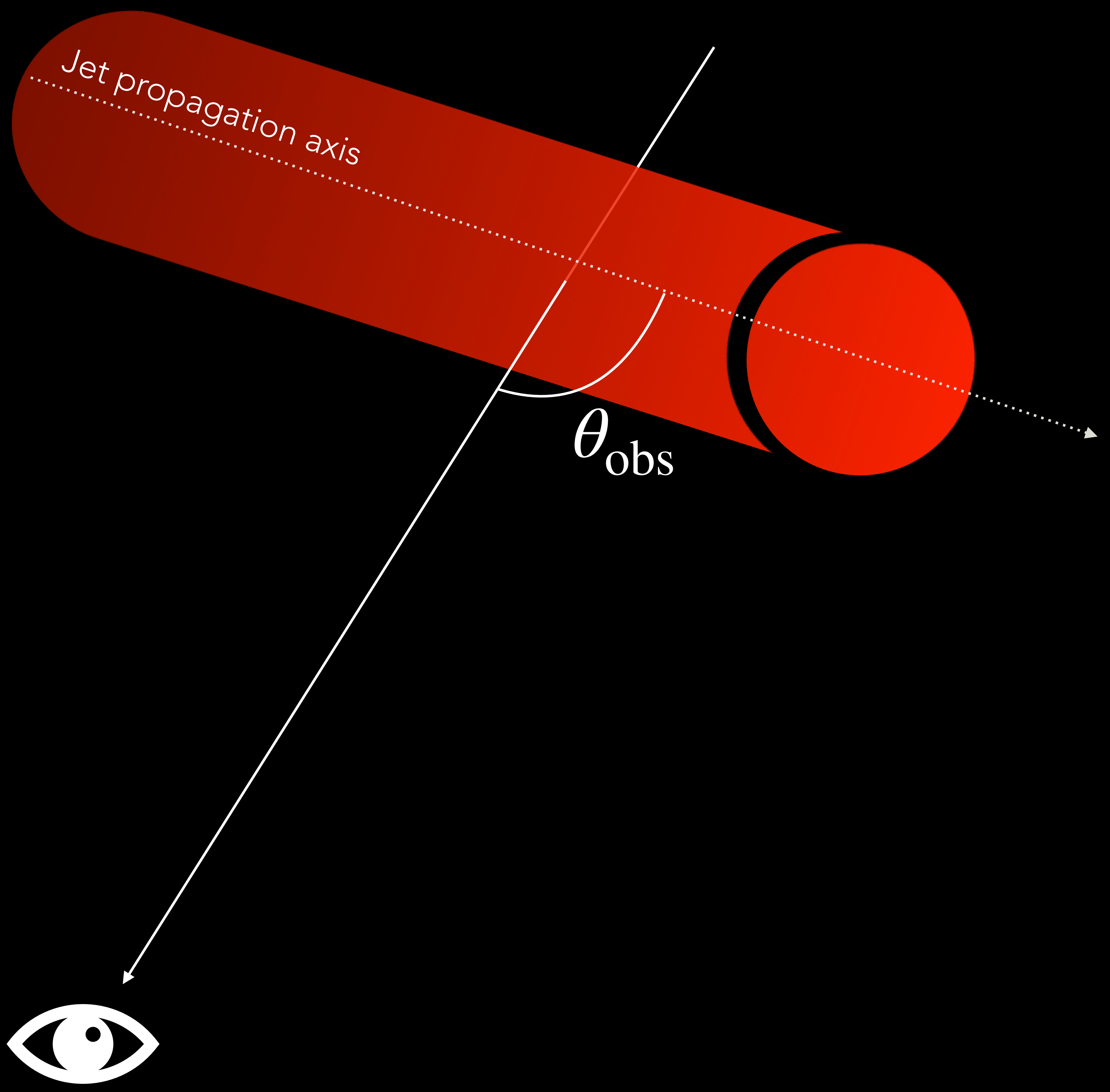

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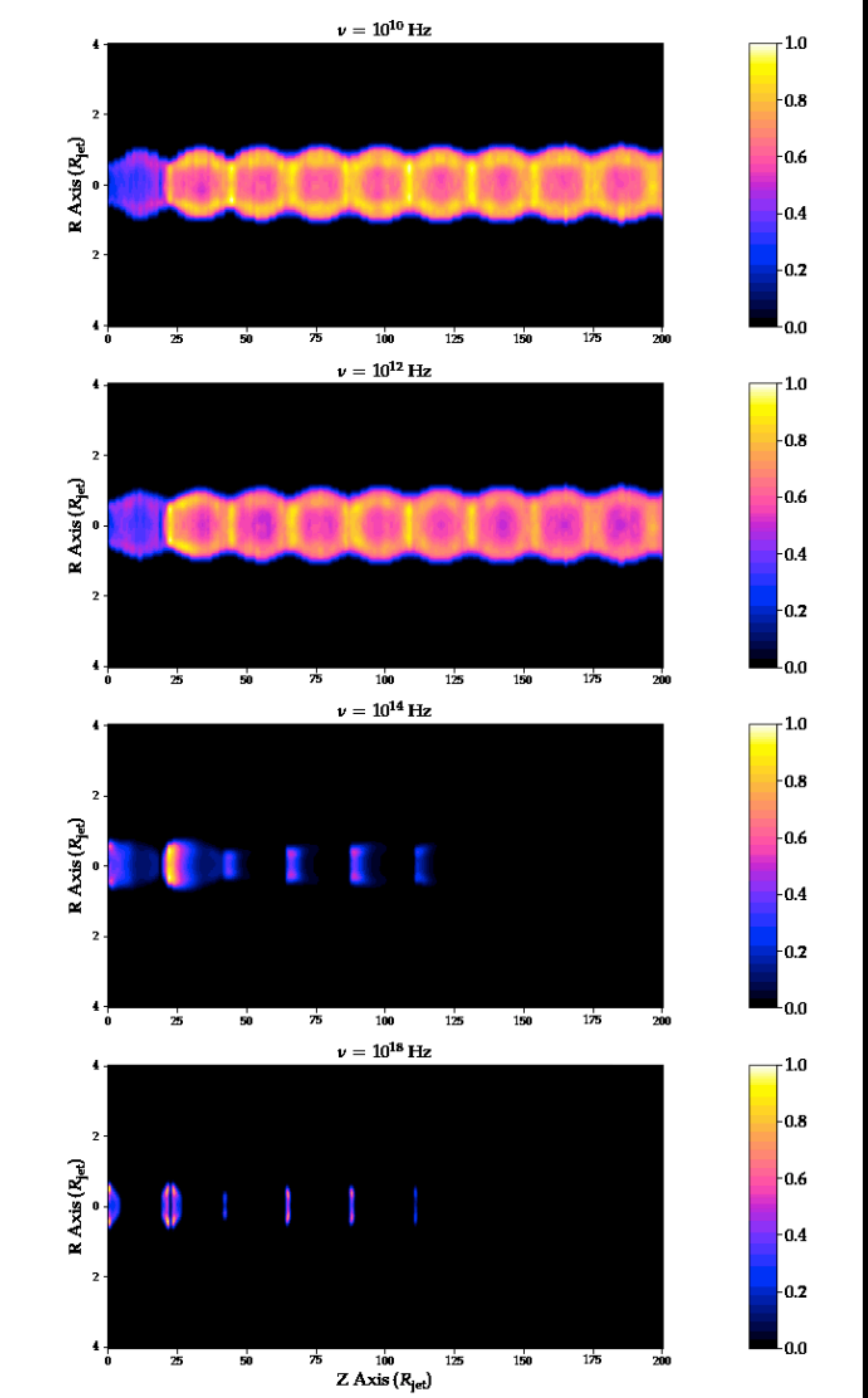

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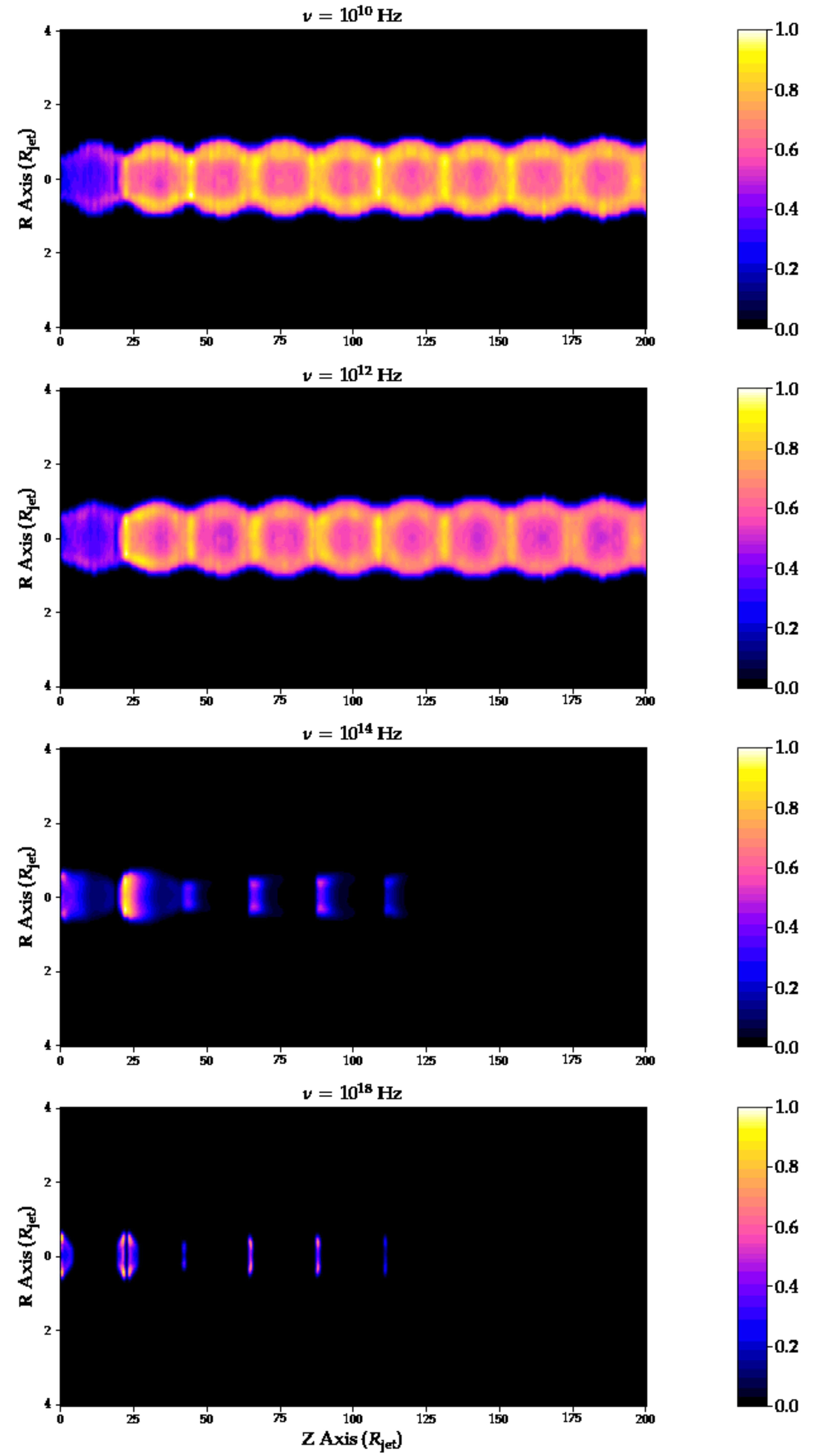

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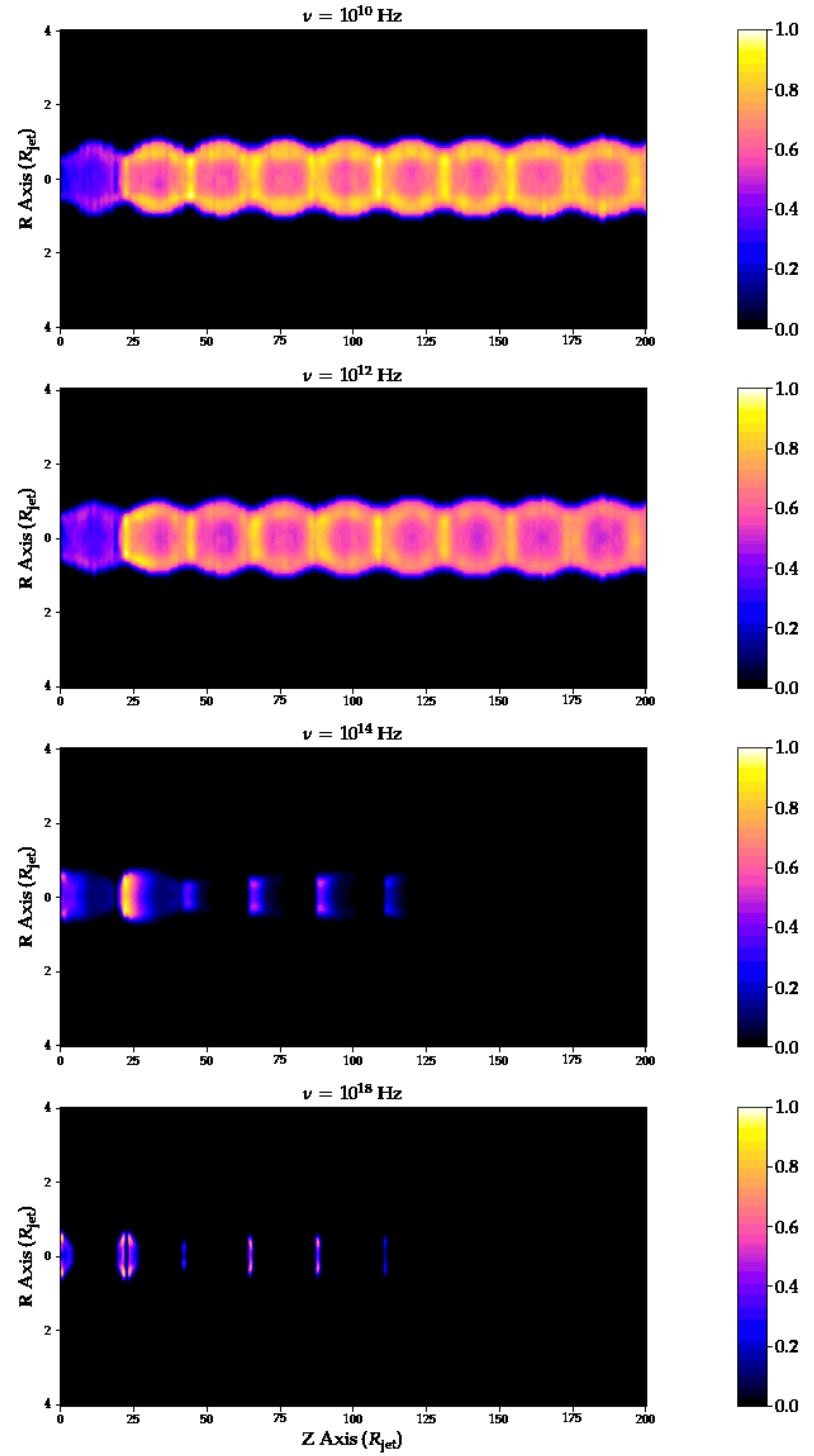
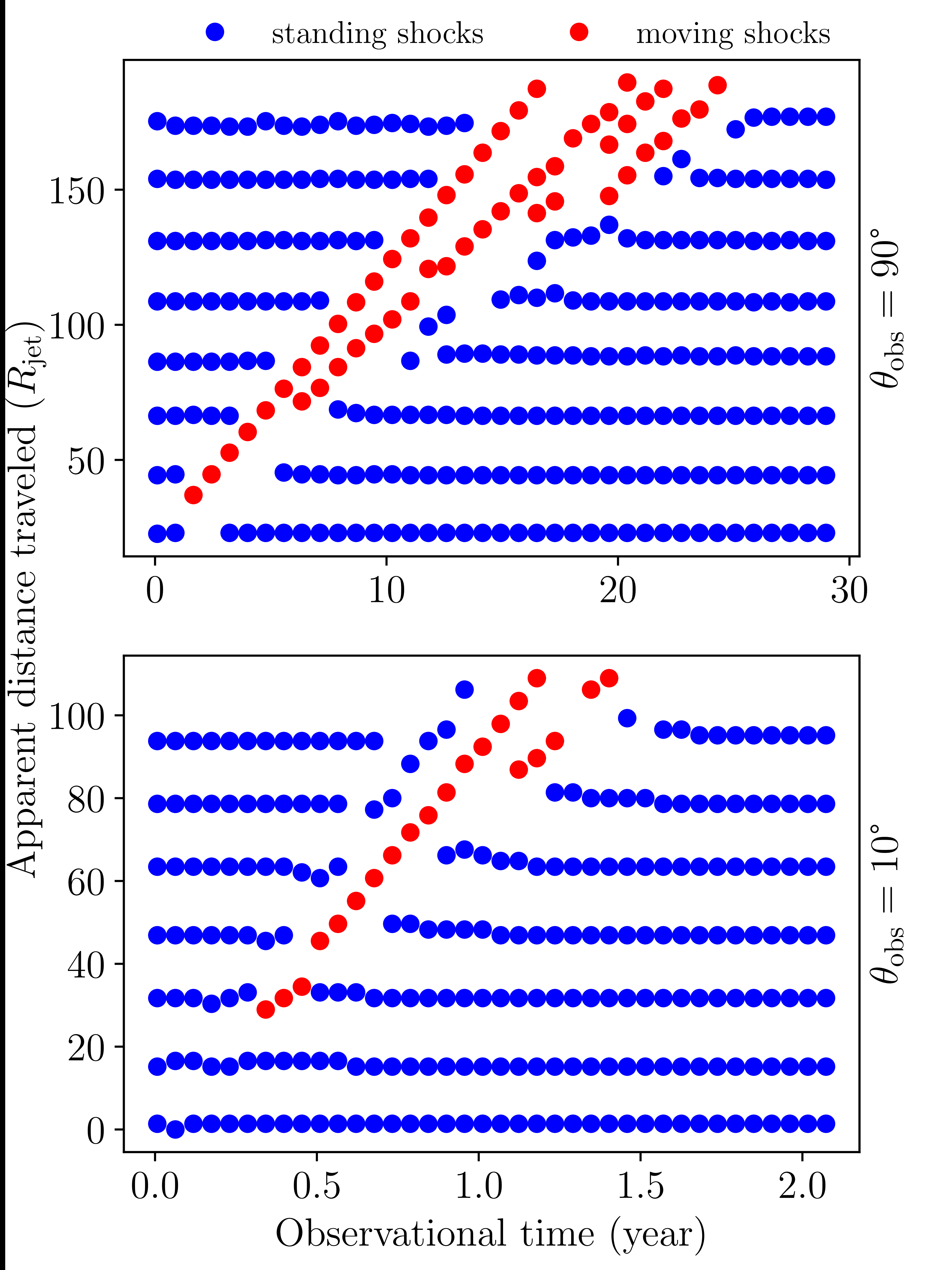


OBSERVATIONAL MARKER N°1 : THE FORK

- We report the distance traveled by moving & standing regions in time.
- Since the beginning, the leading moving shock is localized.
- A relaxation wave appears during the third shock - shock interaction and propagates at lower speed.

For low opacity and / or a high enough observation angle, we expect to see « fork » events in VLBI data.



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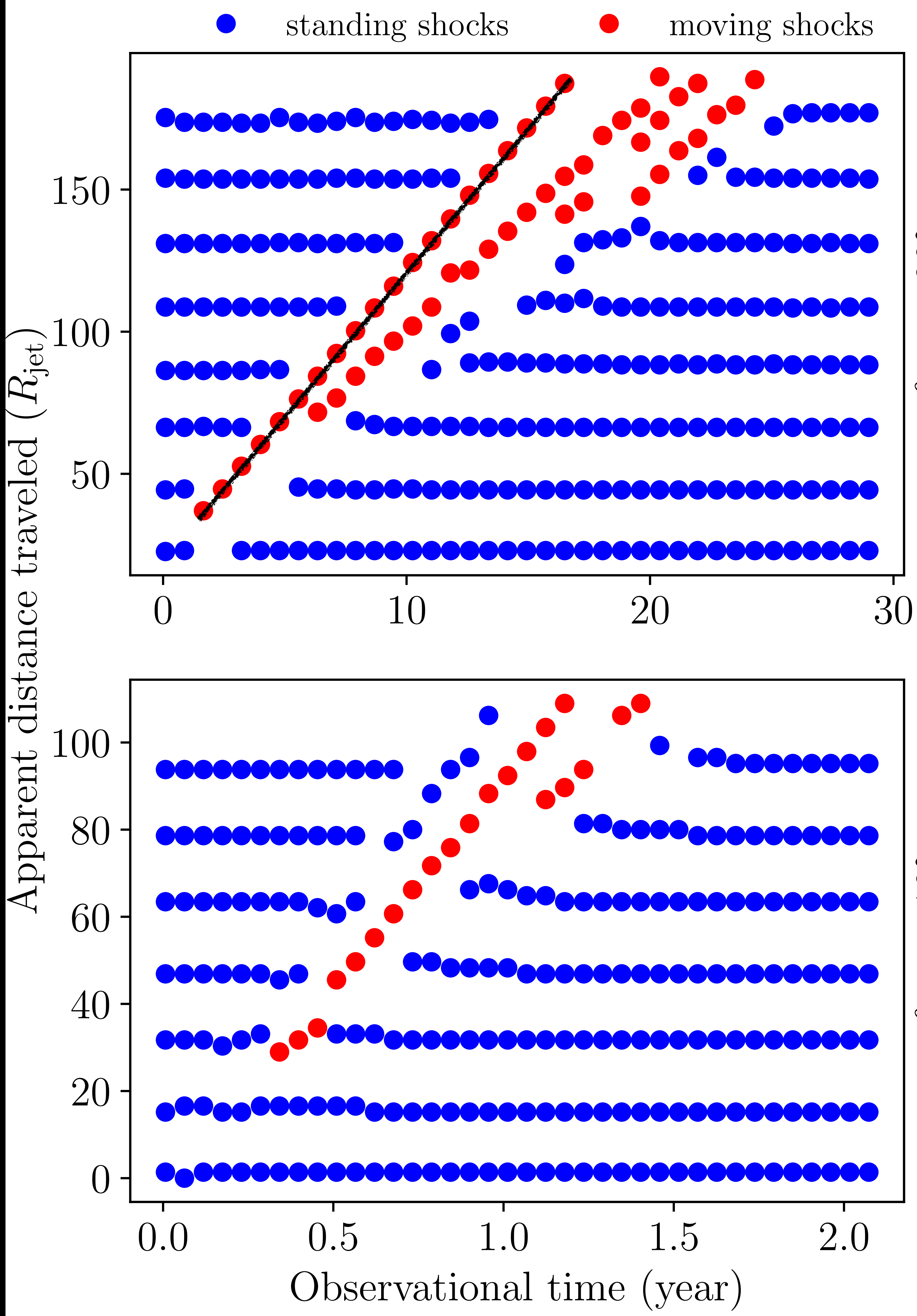

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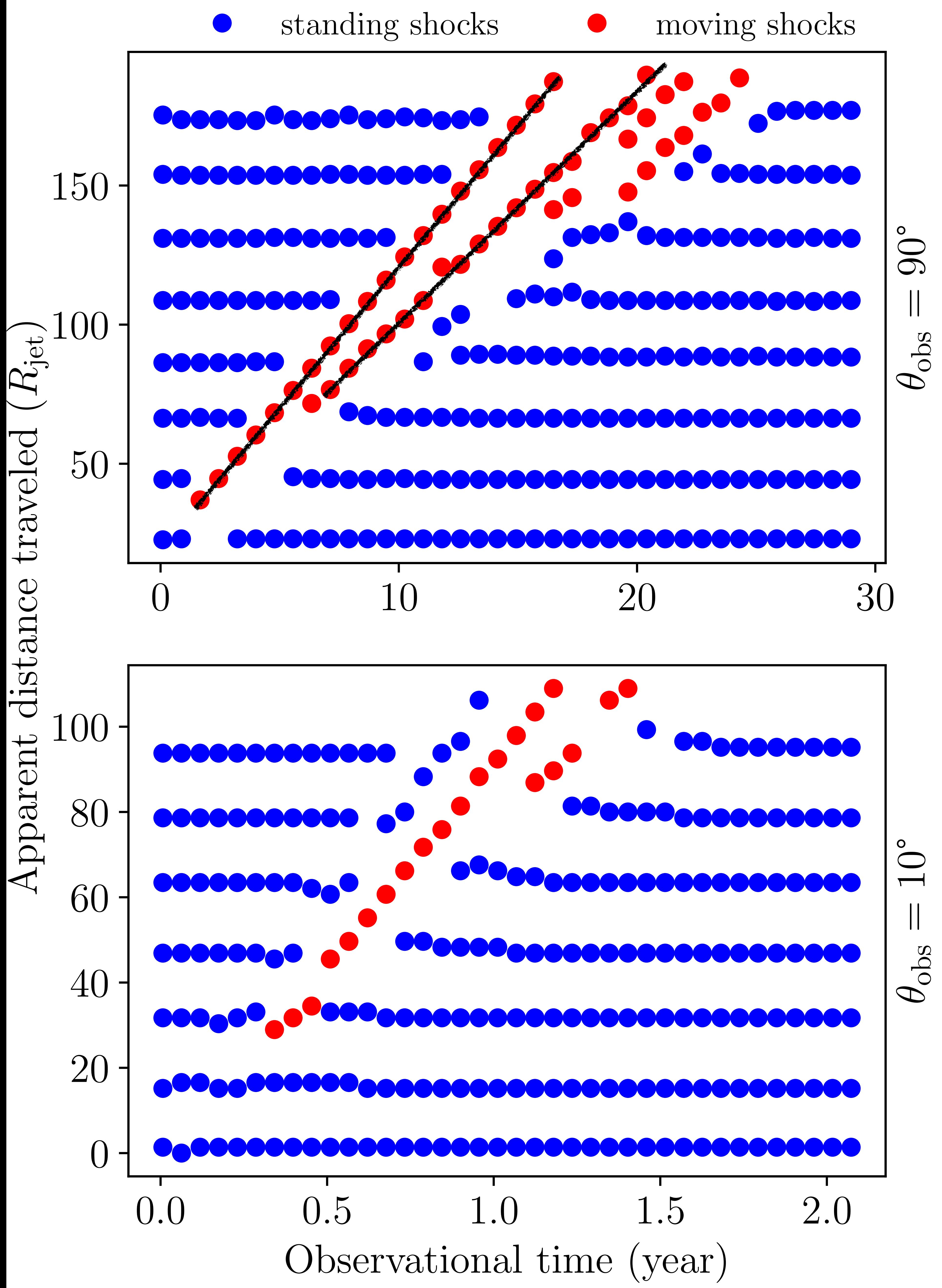

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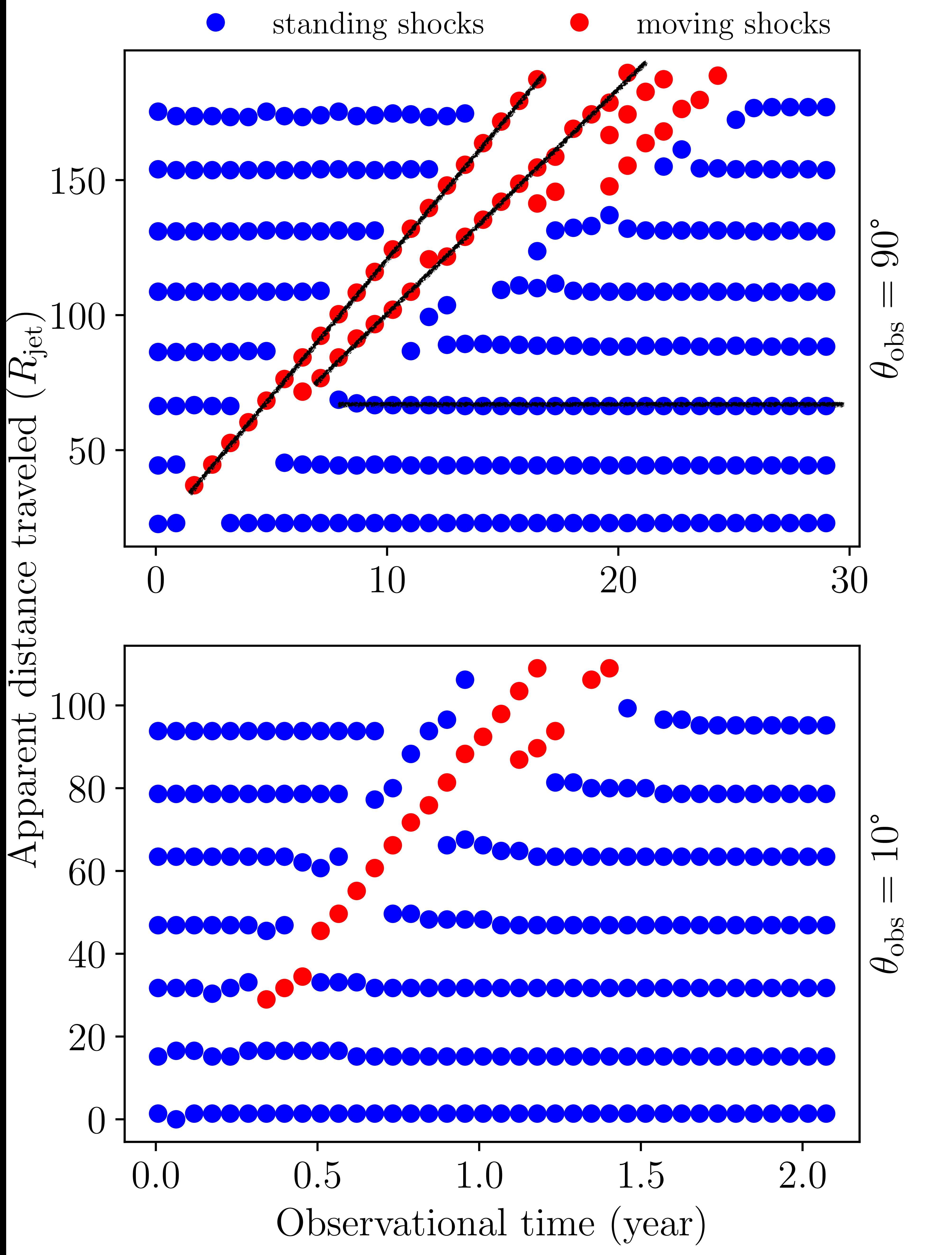
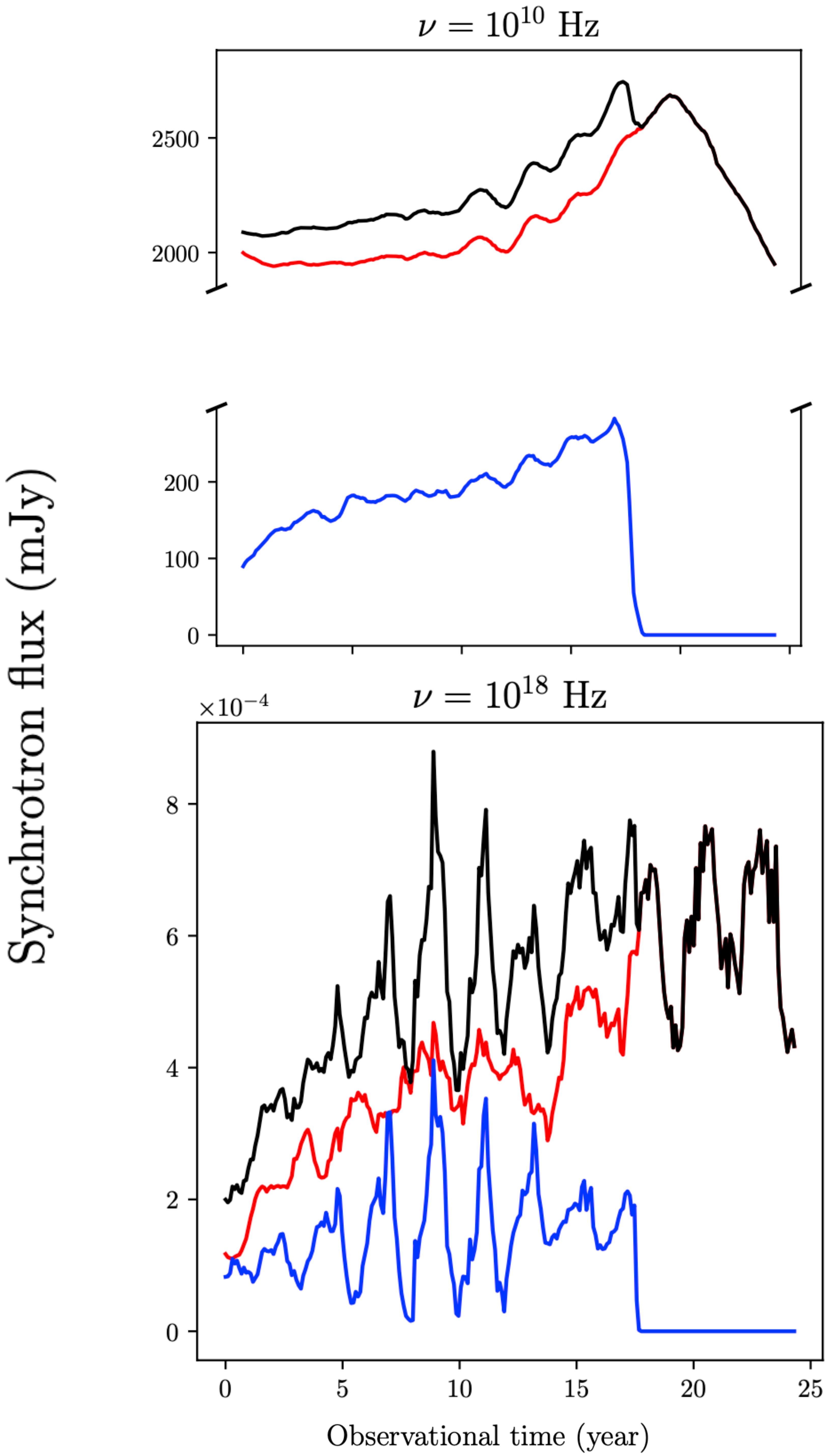


OBSERVATIONAL MARKER N°2 : THE ECHO

- We distinguish emissions coming from the ejecta / the jet ($\theta_{obs} = 90°$).
- Low frequencies :
  - Emission & variability dominated by jet and relaxation waves.
- High frequencies :
  - Clear echo after shock - shock interactions.

We expect to detect an echo for all frequencies, but especially in the X-ray band.



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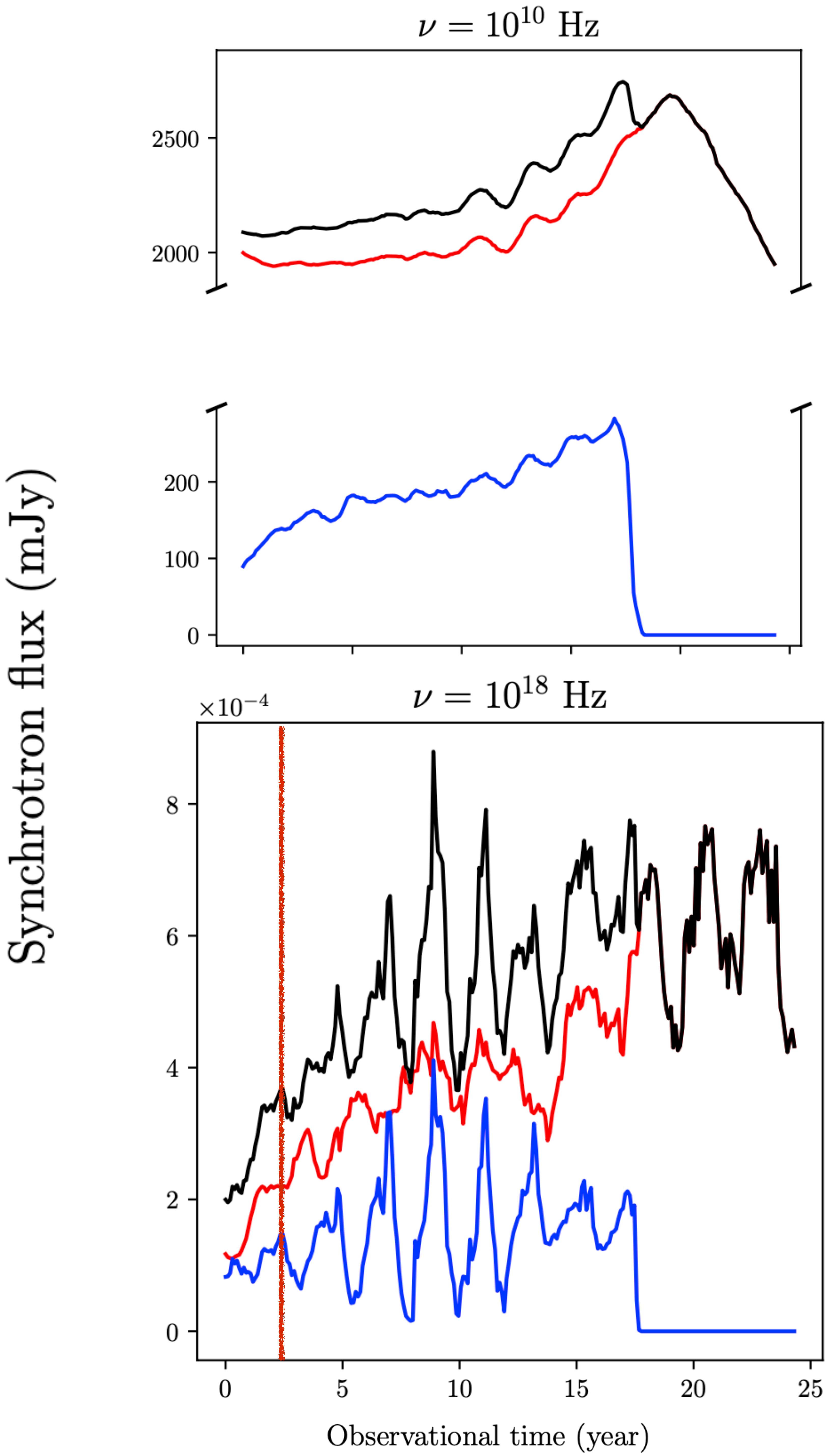

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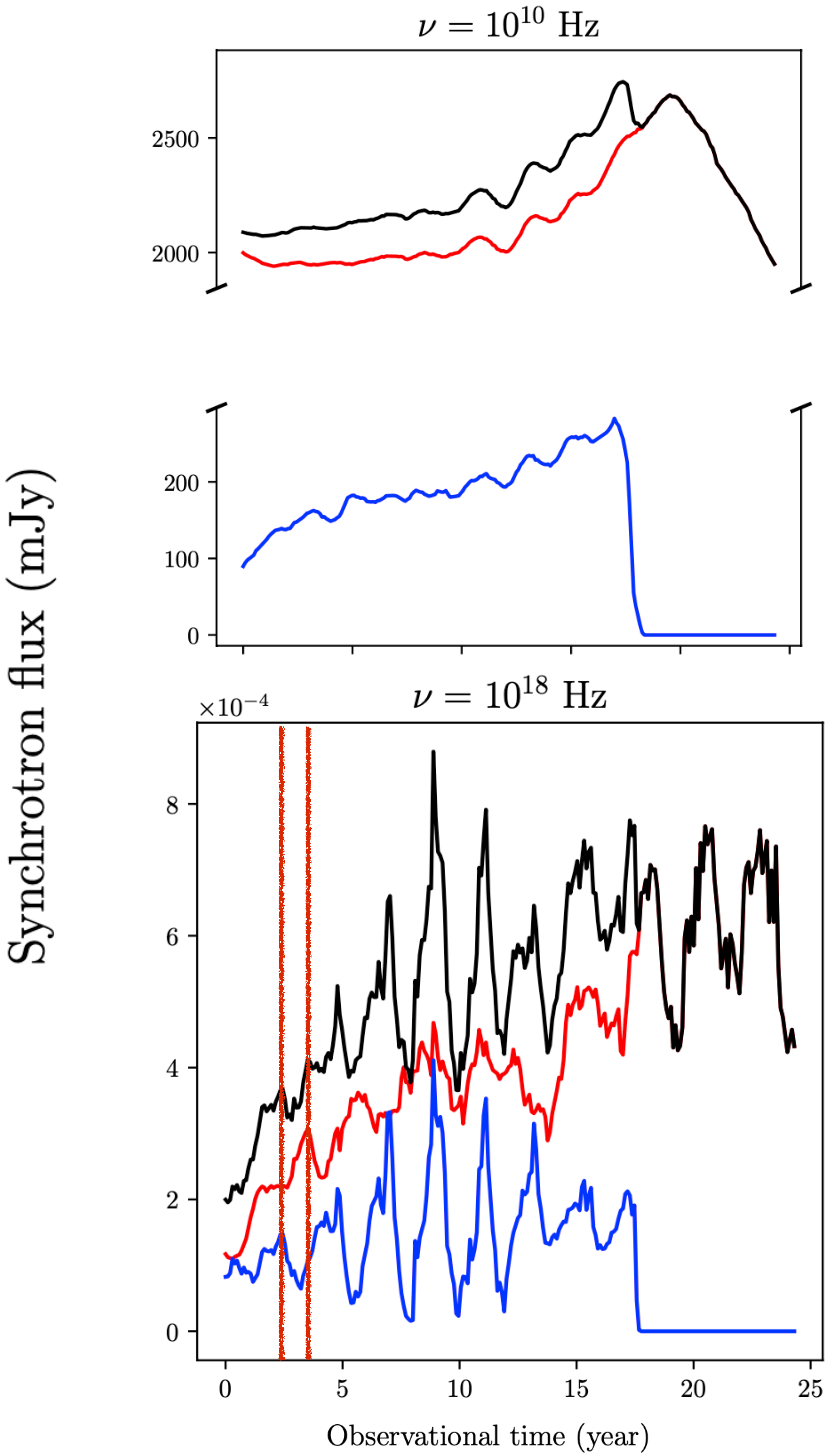
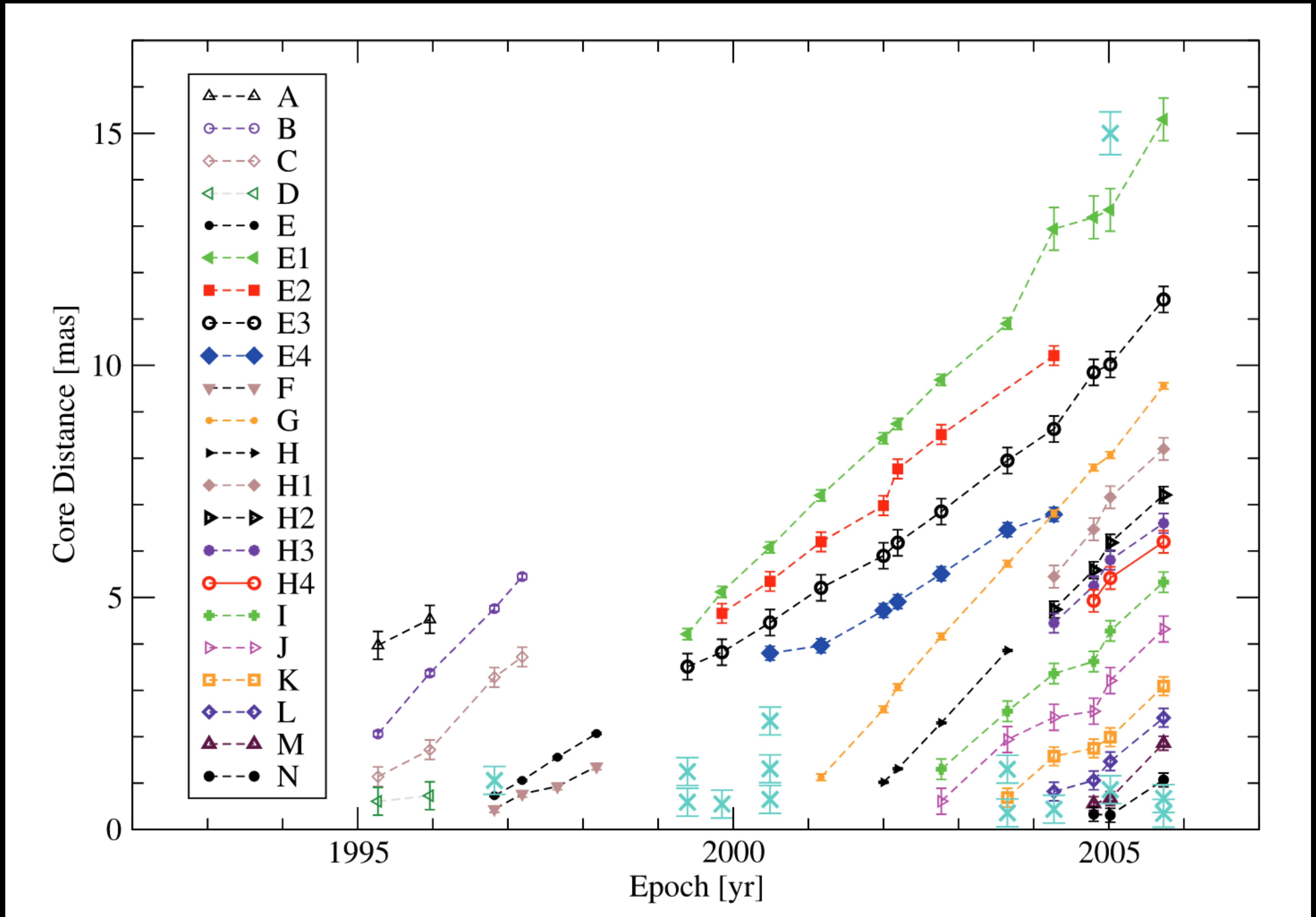


APPLICATION TO 3C 111 :

- Trailing components have been detected in 1997 [4].
- Trailing components (**F, E2, E3, E4**) appear in the wake of a leading one (**E, E1**), after interactions with standing shocks.
- Associated radio flare events have been observed with asymmetry due to emission from relaxation shocks.
- Their origin are still matter of debate [1] but **our scenario can explain fork events and the outburst.**



Core separation of components vs. time [4].

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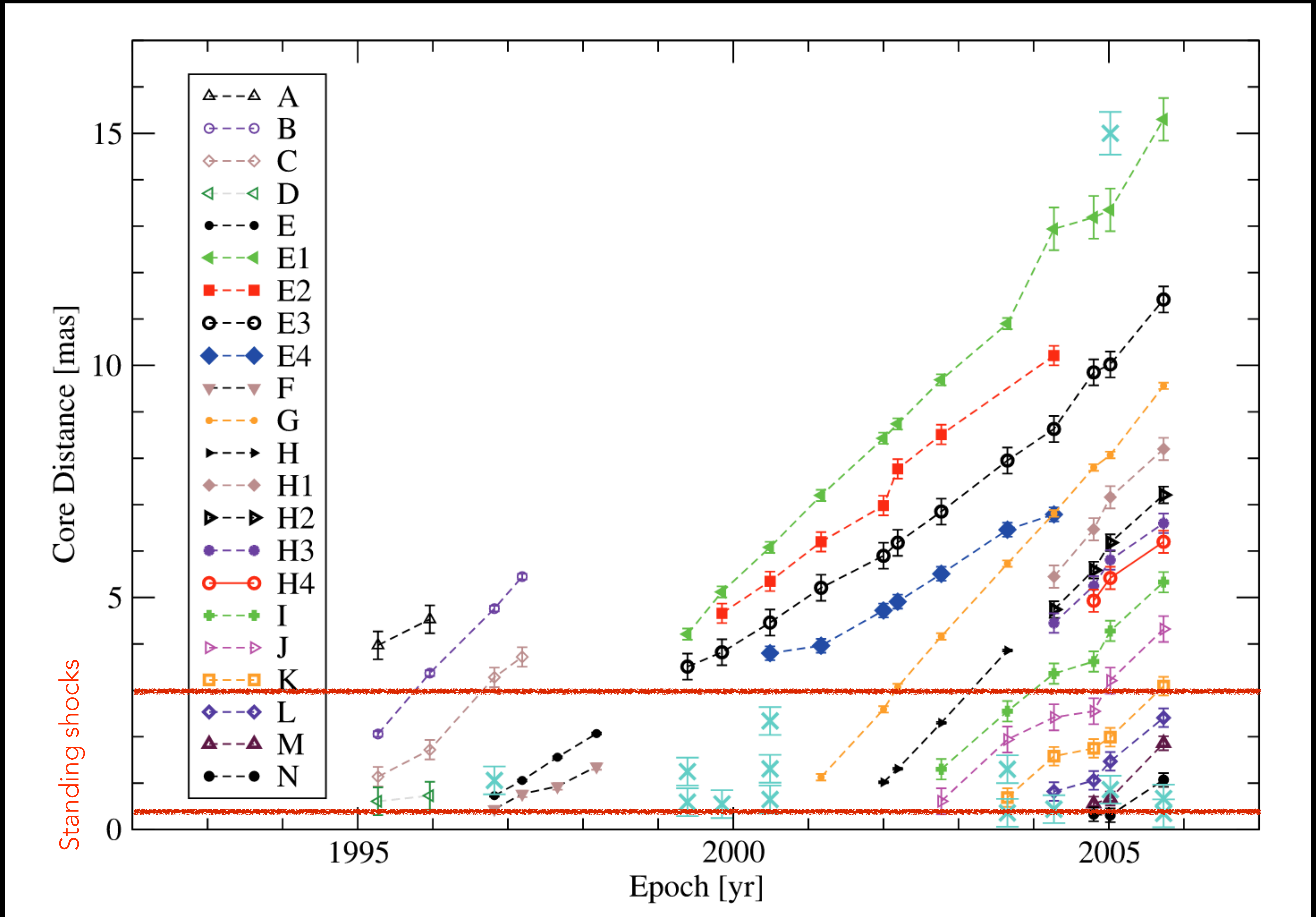

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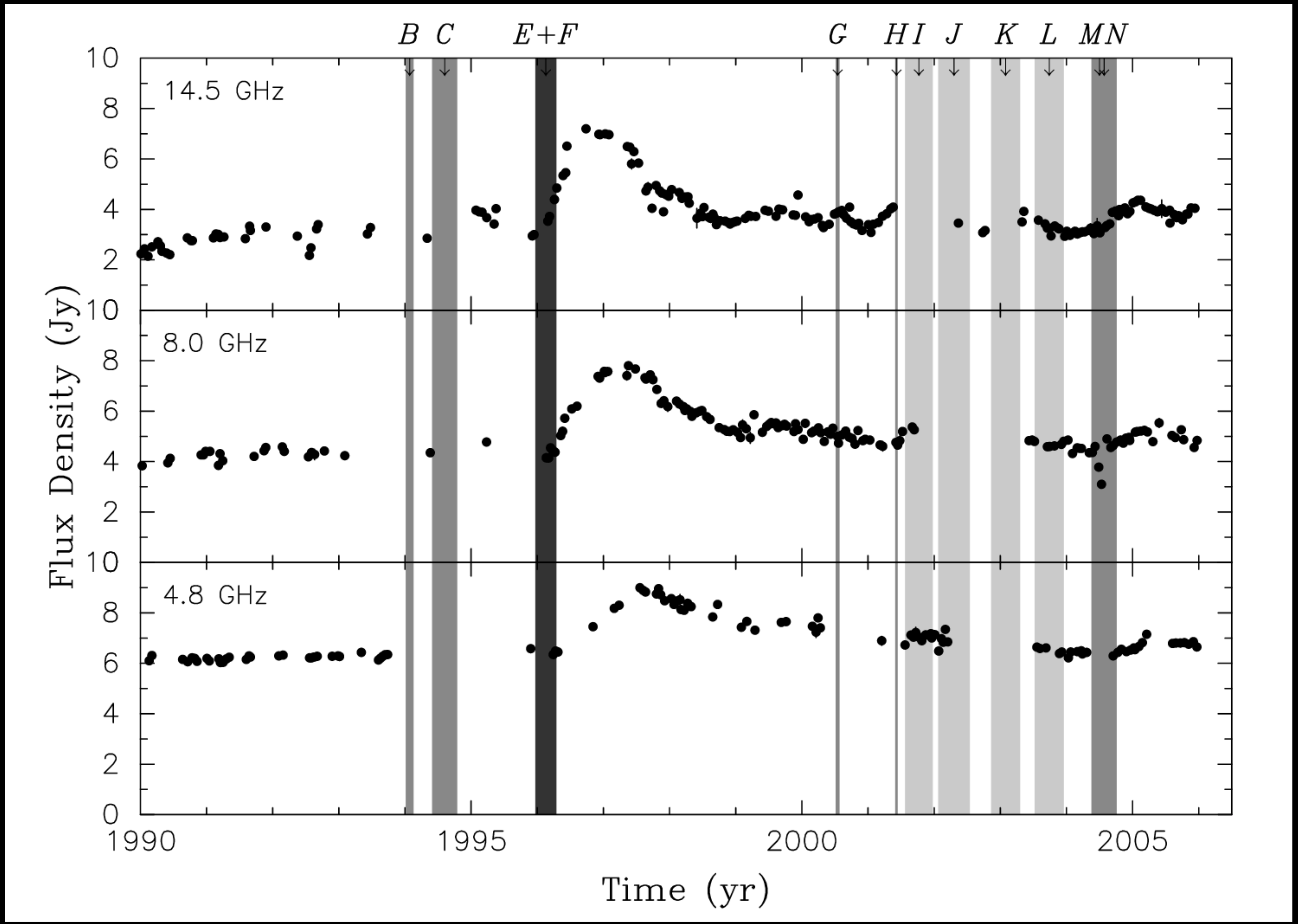

Light curves of 3C 111 at 4.8, 8 and 14.5 GHz [4].

KEY TAKEAWAYS

Paper soon to be submitted to A&A !

- Thanks to a MWL study we aim to identify two relaxation waves observational markers :

  I. At low frequency : fork events could be detected and give us information on the jet physical parameters.

  II. At all frequencies (especially high) : flare echo after shock - shock interactions coming from shock oscillations and / or relaxation shocks.

Comparison with 3C 111 is promising and dedicated simulations need to be done. Relaxation waves can help us to constraint the jet physics and build a coherent model of AGN.

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